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(54) Distance measuring sensor

(57) A distance measuring sensor comprising a magnetic field generator 1, first, second, and third converters near one another at a position 6 to convert magnetic field to voltage, the magnetic field being generated through the magnetic field generator, and a detector, adder and operational processing circuit, wherein the outputs of the converters are applied to the detector to get data relating to the distance between the magnetic field generator 1 and the converters 6. in the embodiment the magnetic field generator and the converter assembly each comprise three members arranged on mutually orthogonal magnetic axes. A first generator member is energized, and a signal induced in each of the three converter members is squared and stored. The same is repeated when the second and third generator members are energised in turn. The nine squares thus stored are summed; and the reciprocal of the sixth root of the sum is determined, as being a linearly function of the distance between the generator 1 and the converters 6.

FIG. 1

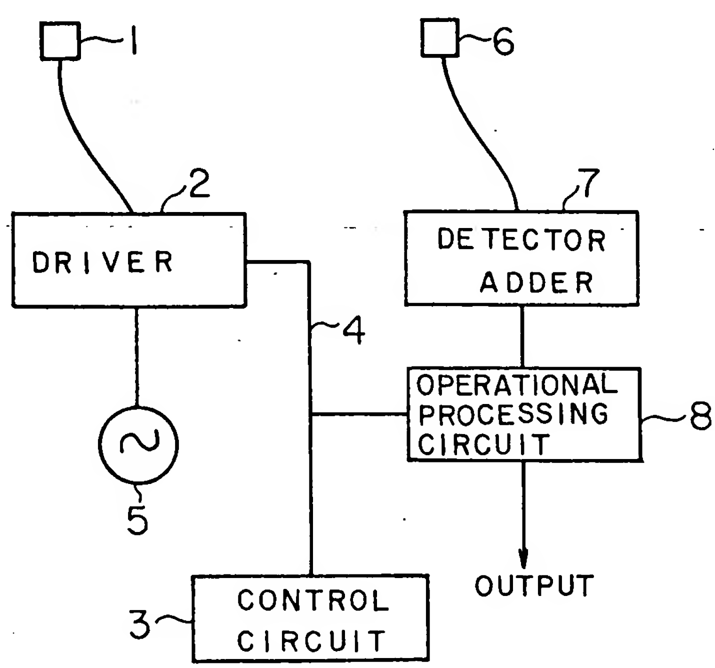

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FIG. 1

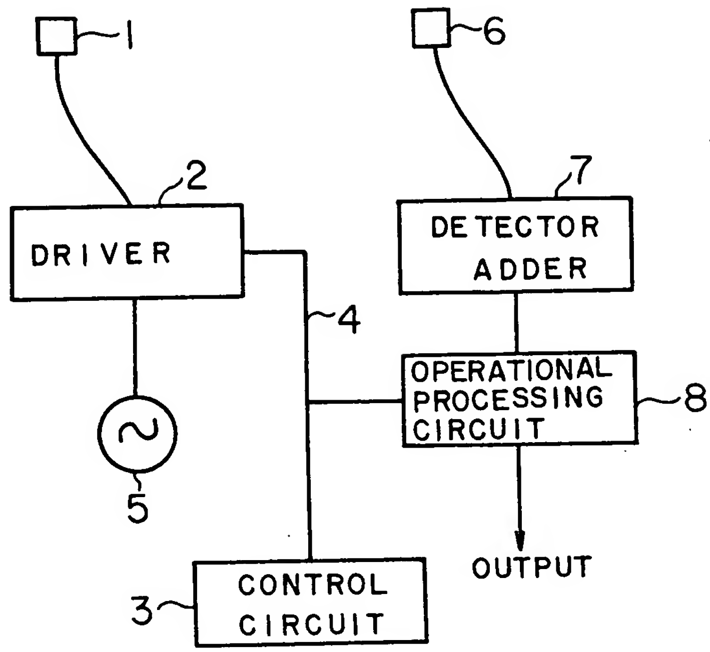


FIG. 2

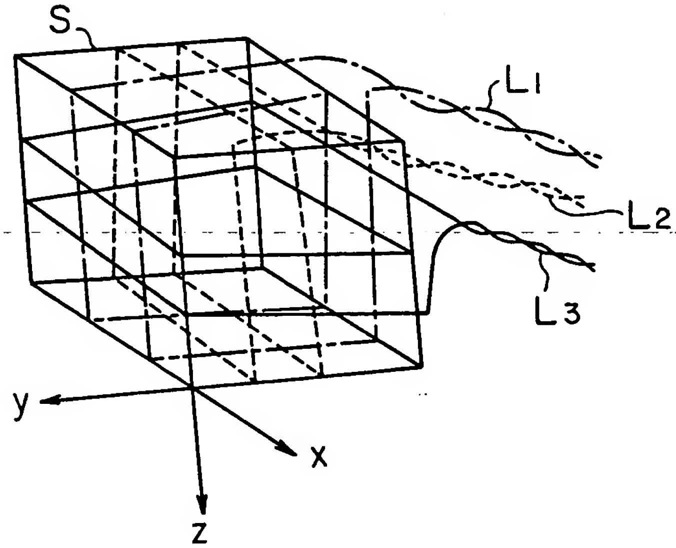


FIG. 3

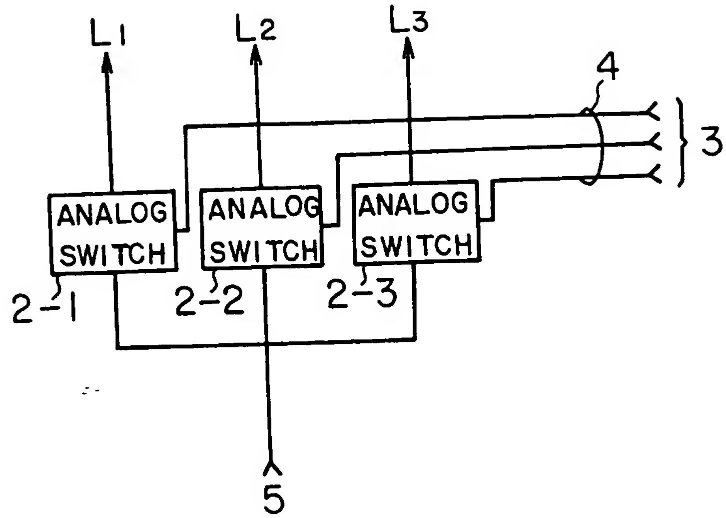

L1
L2
L3
4
3
ANALOG SWITCH
ANALOG SWITCH
ANALOG SWITCH
2-1
2-2
2-3
5

FIG. 4

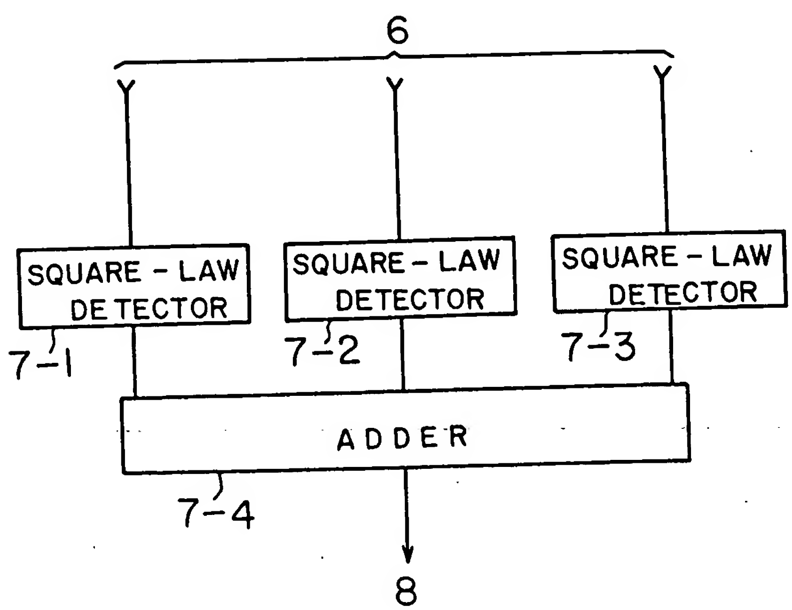

6
SQUARE - LAW DETECTOR
SQUARE - LAW DETECTOR
SQUARE - LAW DETECTOR
7-1
7-2
7-3
ADDER
7-4
8

FIG. 5

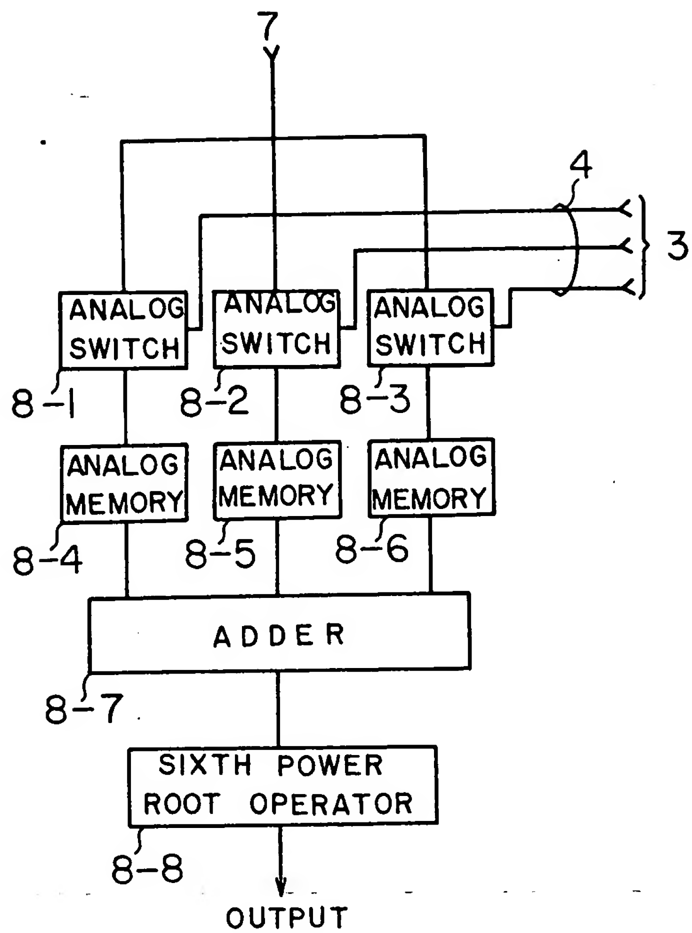

7
4
3
ANALOG SWITCH
ANALOG SWITCH
ANALOG SWITCH
8-1
8-2
8-3
ANALOG MEMORY
ANALOG MEMORY
ANALOG MEMORY
8-4
8-5
8-6
ADDER
8-7
SIXTH POWER ROOT OPERATOR
8-8
OUTPUT

FIG. 6

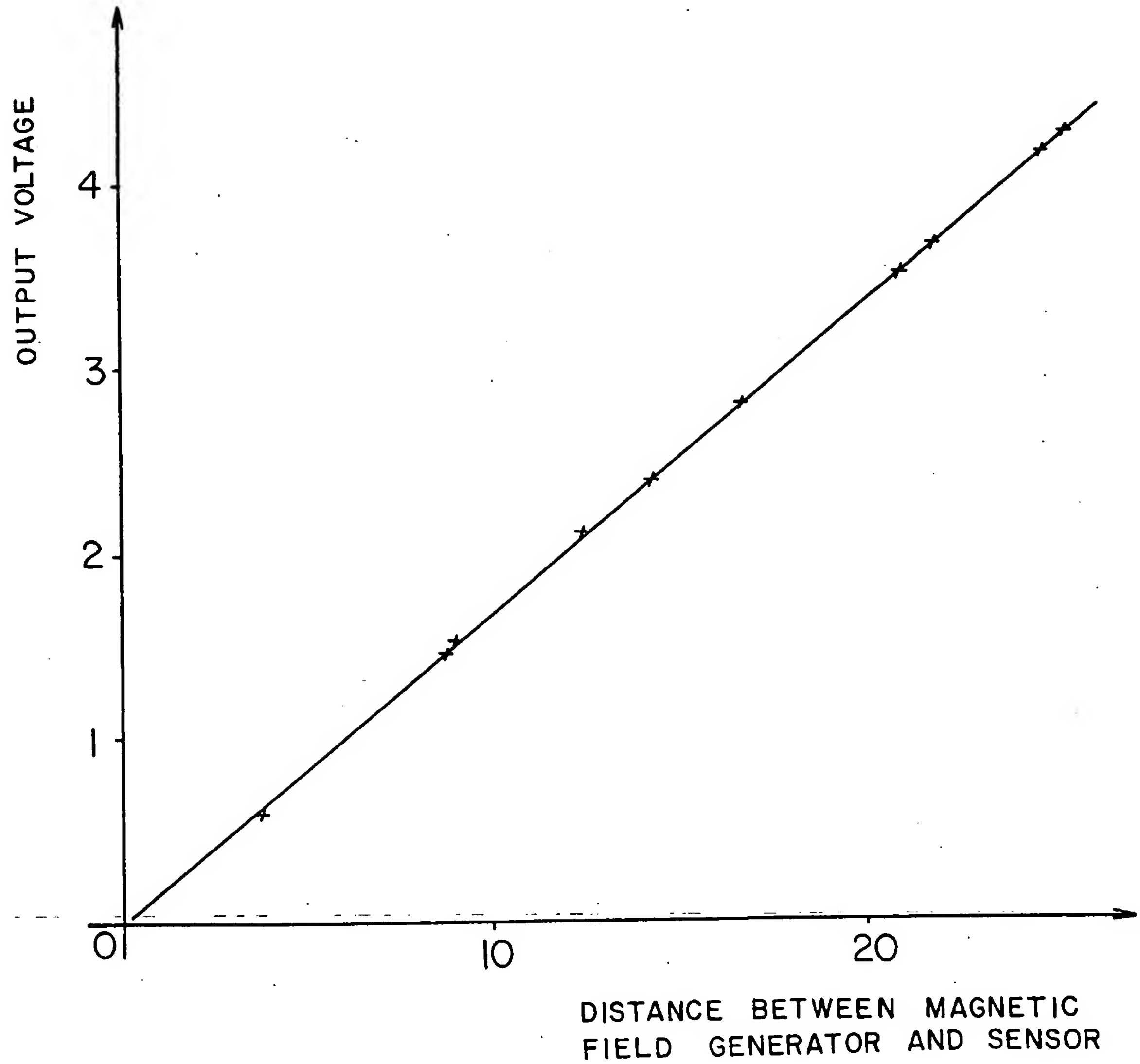
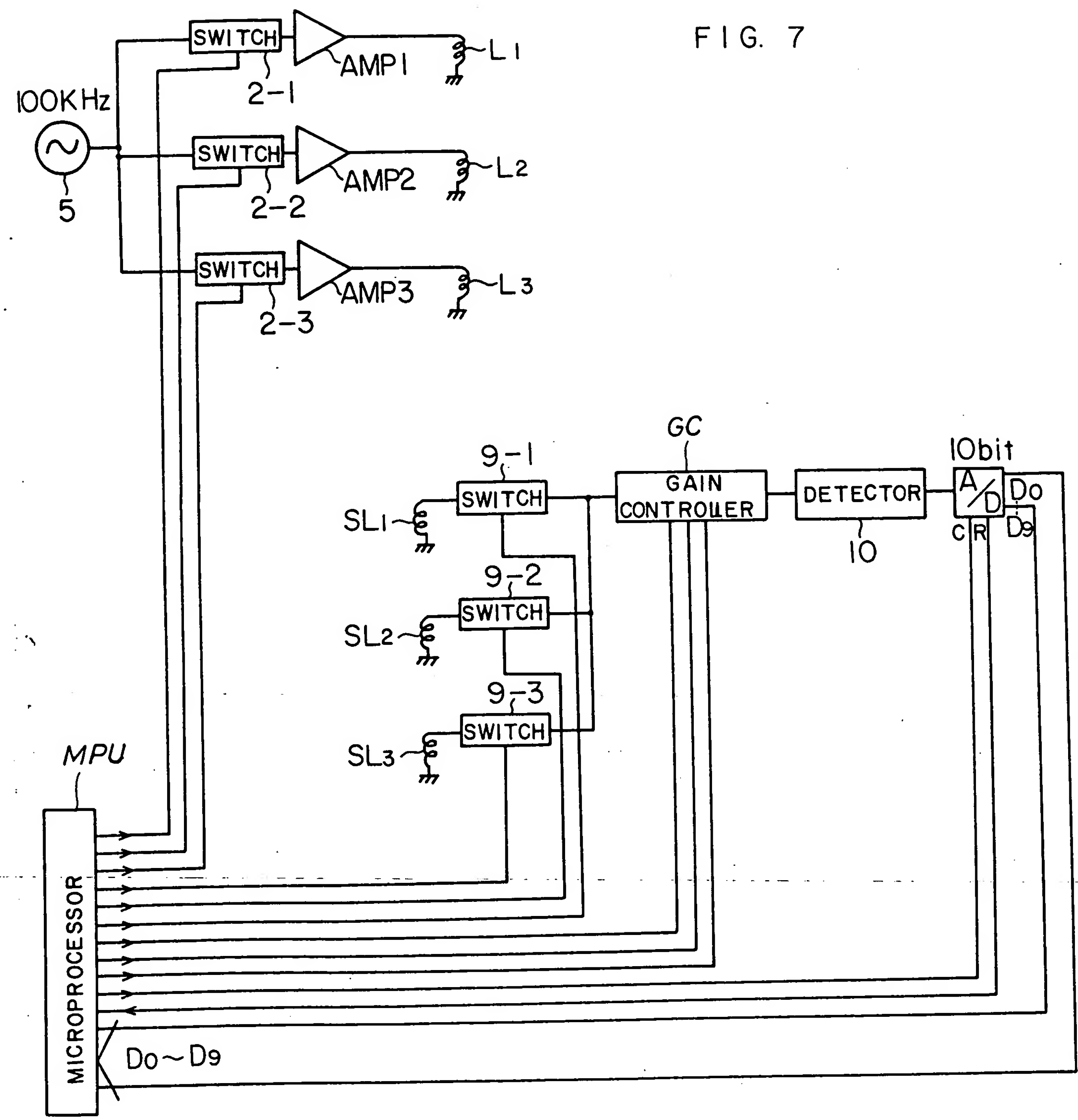

OUTPUT VOLTAGE
4
3
2
1
0
10
20
DISTANCE BETWEEN MAGNETIC FIELD GENERATOR AND SENSOR

FIG. 7



SWITCH
SWITCH
SWITCH
AMP1
AMP2
AMP3
L1
L2
L3
2-1
2-2
2-3
100KHz
5
9-1
9-2
9-3
SWITCH
SWITCH
SWITCH
SL1
SL2
SL3
GC
GAIN CONTROLLER
DETECTOR
10
10bit
A/D
C
R
Do
D9
MPU
MICROPROCESSOR
Do~D9

SPECIFICATION
Distance-measuring sensor

BACKGROUND OF THE INVENTION

The present invention relates to a device for measuring the distance between two points.

Various sensors have been developed along with the progress of micro-computers. Among these sensors are included the one for measuring the distance between two points.

The distance is conventionally measured by the angle of a rotary encoder rotated, the encoder being arranged, as a distance-measuring sensor, at a point where two sides are crossed like compasses. Assuming that the length of one side of the compasses is l, the distance can be lead from $2 l \sin \theta/2$ wherein θ represents the angle formed by two sides of the compasses.

The distance is also measured using the capacity of electrodes arranged at both ends of the distance to be measured. Assuming that electrodes area is s and that the distance is d, the capacity c becomes equal to $\varepsilon s/d$ wherein ε represents the dielectric constant of dielectrics present between the electrodes. The distance d can be obtained from this equation $c = \varepsilon s/d$.

The distance-measuring sensor like compasses was limited in use because it specified two points mechanically. The other method of using electrodes capacity was likely to be influenced under circumstances, thus making errors because of humidity, position of measuring person and so on.

SUMMARY OF THE INVENTION

The present invention is therefore intended to eliminate the drawbacks and the object of the present invention is thus to provide a distance-measuring sensor capable of measuring the distance between two points through the degree of magnetic coupling, and comprising at least one magnetic field generator means for generating magnetic field, first, second and third transformer means arranged in the vicinity of said magnetic field generator means to transform magnetic field generated through the magnetic field generator means to voltage, and an operational means, wherein outputs of said transformer means are applied to the operational means to obtain distance data from the magnetic field generator means as well as from the transformer means.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing a first embodiment of the present invention.

Fig. 2 shows the construction of magnetic field generating and sensor coils.

Fig. 3 is a block diagram showing a driver.

Fig. 4 is a block diagram showing detectors.

Fig. 5 is a block diagram showing an operational process circuit.

Fig. 6 shows a characteristic curve relating to distances and output voltages of the operational means.

Fig. 7 is a circuit diagram showing a second embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 is a circuit diagram showing a first embodiment according to the present invention. A magnetic field generator 1 consists of coils for generating magnetic field in three directions. Fig. 2 shows the structure of coils which form the magnetic field generator 1. Each of coils L1—L3 is wound twice around a cube s to generate magnetic field in three directions. Coils L1—L3 serve to generate magnetic field along axes x, y and z. The magnetic field generator 1 is connected to a driver 2, which selects the coils L1—L3 through a signal line 4 extending from a control circuit 3, to output alternating signals obtained from an oscillator 5. Fig. 3 is a circuit diagram showing a driver. Inputs of analog switches 2—1 — 2—3 are connected to the oscillator 5 while the control line 4 to the control circuit 3. Outputs of the analog switches 2—1 — 2—3 are connected to the coils L1, L2 and L3 of the magnetic field generator 1. The analog switches 2—1 — 2—3 selected through the control line 4 are turned on to output alternating signals of the oscillator 5. A sensor 6 has coils SL1—SL3 same in structure as those L1, L2 and L3 of the magnetic field generator 1 shown in Fig. 2, and serves to detect magnetic field in three directions.

Outputs of the sensor 6 are applied to a detector adder 7, which serves to square-law detect and add signals obtained from the sensor 6. Fig. 4 shows a circuit arrangement of the detector adder 7. Signals through the coils SL1—SL3 of the sensor 6 are applied to square-law detectors 7—1 — 7—3 and square-law detected there. Detected signals of the square-law detectors 7—1 — 7—3 are applied to an adder 7—4 and added there. Output of the adder 7—4 becomes proportional to a value obtained by squaring the maximum scalar quantity of alternating-current magnetic field vector at the position of the sensor 6.

Outputs of the detector adder 7 are applied to an operational process circuit 8, which functions to add the outputs of the detector adder 7, said outputs being obtained through magnetic field generated by each of the magnetic field generating coils L1—L3. Fig. 5 is a circuit diagram showing the operational process circuit 8.

Responsive to the switching operation of each of analog switches 2—1 — 2—3 of the driver 2,

analog switches each of analog switches 8—1 — 8—3 is turned on. Outputs of the analog switches 8—1 — 8—3 are applied to analog memories 8—4 — 8—6. For example, when the analog switch 8—1 is turned on responsive to the switching operation of the analog switch 2—1 of the driver 2, the analog switch 8—2 is turned on responsive to the switching operation of the analog switch 2—2, and the analog switch 8—3 is turned on responsive to the switching operation of the analog switch 2—3, outputs of the detector adder 7 obtained from magnetic field generated through the magnetic field generating coils L1—L3 are stored in the analog memories 8—4 — 8—6, respectively.

Outputs of the analog memories 8—4 — 8—6 are applied to and added in an adder 8—7. Namely, values each proportional to the square of each of scalar quantities, at the position of the sensor 6, of magnetic field generated in three directions through the magnetic field generating coils L1—L3 are added.

Output of the adder 8—7 is applied to a sixth power root operator 8—8, which serves to get the sixth power root of input signal and to output its reciprocal or inverse or reverse number. Fig. 6 is a characteristic curve showing the relation of distance between the magnetic field generator 1 and the sensor 6 relative to output voltage of the operator 8—8. The relation changes substantially linear. Namely, output voltage of the operational process circuit 8 is proportional to the distance between the magnetic field generator 1 and the sensor 6. Oscillation frequency of the oscillator 5 is 100 kHz. The sensor and the magnetic field generator are changed in direction at each of points. Referring to the first embodiment of the present invention shown in Fig. 1, detailed description will be made to signals.

It is assumed that amplitude values of alternating signal outputs of sensor coils SL1, SL2 and SL3 are V11, V12 and V13 when outputs of the oscillator whose oscillation frequency is 100 kHz are applied to the coil L1 of the magnetic field generator. These outputs V11, V12 and V13 are applied to and detected and then squared in the square-law detectors 7—1, 7—2 and 7—3. Namely, outputs of the square-law detectors 7—1, 7—2 and 7—3 become $V11^2$, $V12^2$ and $V13^2$. These signals are added by the adder 7—4 to output $V11^2 + V12^2 + V13^2$. When output of the oscillator 5 is applied to the coil L1, the analog switch 8—1 is turned on, thus allowing the data $V11^2 + V12^2 + V13^2$ to be stored in the analog memory 8—4. It is then assumed that amplitude values of alternating signal outputs of the sensor coils SL1, SL2 and SL3 are V21, V22 and V23 when output of the oscillator is applied to the coil L2 of the magnetic field generator. These outputs V21, V22 and V23 are similarly square-law detected by the square-law detectors 7—1, 7—2 and 7—3 and then added by the adder 7—4, whose output becomes $V21^2 + V22^2 + V23^2$. Since the analog switch 8—2 is turned on this time, the data $V21^2 + V22^2 + V23^2$ is stored in the analog memory 8—5. Providing that outputs of the sensor coils SL1, SL2 and SL3 are V31, V32 and V33 when output of the oscillator is applied to the coil L3 of the magnetic field generator, $V31^2 + V32^2 + V33^2$ is stored in the analog memory 8—6.

Outputs of the analog memories 8—4, 8—5 and 8—6 are applied to the adder 8—7 so that output of the adder 8—7 becomes $V11^2 + V12^2 + V13^2 + V21^2 + V22^2 + V23^2 + V31^2 + V32^2 + V33^2$. This output is treated by the sixth power root operator 8—8 to get its sixth power root, which is then to become reciprocal or inverse in number. Output OUT of the adder 8—8 is thus formulated as follows:

$$\mathrm{OUT} = \frac{1}{\sqrt[6]{V11^2 + V12^2 + V13^2 + V21^2 + V22^2 + V23^2 + V31^2 + V32^2 + V33^2}}$$

All of the above-described circuits are intended to make operational treatment about inputs so as to output their resultants as voltage values. These outputs are thus multiplied by specified constants, but these constants are here assumed to be one for the clarity of description. Namely, the axis of ordinates in Fig. 6 also represents voltage values.

Fig. 7 shows a second embodiment of the present invention. Outputs of the oscillator 5 whose oscillation frequency is 100 kHz are applied to the analog switches 2—1, 2—2 and 2—3. Their outputs are amplified by amplifiers AMP1, AMP2 and AMP3 to drive the coils L1, L2 and L3, which are same in construction as those shown in Fig. 2. Control terminals of the analog switches 2—1, 2—2 and 2—3 are connected to a micro-processor unit MPU. The coils SL1, SL2 and SL3 of the sensor are connected to the analog switches, respectively. Similarly to the coils L1, L2 and L3, these coils SL1, SL2 and SL3 are same in construction as those shown in Fig. 2. Outputs of the analog switches 9—1, 9—2 and 9—3 are applied to a gain controller GC. Control terminals of the analog switches 9—1, 9—2 and 9—3 are connected to the micro-processor unit MPU. Output of the gain controller GC is connected to a detector 10, while control terminals thereof are connected to the micro-processor unit MPU. Output of the gain controller GC is applied to a 10-bit analog/digital converter A/D through the detector 10, which serves to convert AC voltage to DC voltage and to run peak detection, for example. Data outputs of the analog/digital converter A/D are applied to the micro-processor unit MPU. The analog switch 2—1 is turned on through the micro-processor unit and alternating-current magnetic field of 100 kHz is generated through the coil L1. This magnetic field is coupled to the sensor coils SL1, SL2 and SL3, through which are generated alternating-current voltages. The analog switch 9—1 is turned on through the micro-processor unit and voltage caused through the coil SL1 is measured. Voltage generated

through the coil SL1 is of alternating current, amplified by the gain controller GC and applied to the analog/digital converter A/D through the detector 10. The analog/digital converter A/D starts its converting process when its terminal C receives signal from the micro-processor unit MPU, and applies signal, which represents measure finish, to the micro-processor unit MPU through its terminal R. When 10-bit outputs of the analog/digital converter A/D are not in a specified range, the micro-processor unit MPU changes a gain of the gain controller GC to bring these outputs into the specified range. The gain controller GC has a three-stage amplifier and changes every 8 times in a range of 1 — 8 × 64 × 512 responsive to control signals applied from the micro-processor unit MPU. Namely, one of 1, 8, 64, 512, 4096, 32768, 262144 and 2097152 is selected. When output D of the analog/digital converter A/D is between "0001111111" and "1111111110" (binary), gain of the gain controller GC is the optimum. If it is small, the gain is made larger. If the gain is 512 and the output of the analog/digital converter A/D is "0001011010", the gain is made 4096. As the result, the output of the analog/digital converter A/D becomes "1011010xxx" wherein the digit x represents either "0" or "1". If the output is "1111111111", the gain is made 64 and measurement is made again through the analog/digital converter A/D. When the resultant obtained by the re-measurement is in the specified range, it is picked up by the micro-processor unit MPU. If the output is still "1111111111", the gain is made smaller and operation similar to that already described above is repeated.

This operation enables mantissa portion to be obtained through the analog/digital converter A/D and index portion to be obtained through the gain controller GC.

The operation described above is similarly made on the sensor coils SL2 and SL3.

Further, the analog switch 2—2 is turned on to drive the coil L2 and the operation is also carried out. Furthermore, the analog switch 2—3 is turned on to drive the coil L3 and the operation is also carried out. More than two of the analog switches 2—1, 2—2 and 2—3 are not turned on simultaneously. Similarly, more than two of the analog switches 9—1, 9—2 and 9—3 are not turned on simultaneously. The operation described above enables the micro-processor unit MPU to get nine data. The micro-processor unit MPU squares each of nine data, adds them, calculates the sixth power root of the resultant, and gets its reciprocal or inverse number, thus enabling the distance between the magnetic field generator 1 and the sensor 6 to be obtained. Since data gained become different depending upon the number of turns and the bulkiness of coils of the magnetic field generator 1 and of the sensor 6, they must be multiplied by a proportional constant obtained.

The micro-processor unit MPU outputs necessary data (not shown). They can be displayed using an eight-segment LED, for example.

The above-described embodiments of the present invention employ coils as the sensor, but Hall elements and the like may be used. When Hall elements are used, magnetic field generated through the magnetic field generator may be of direct current. The coils employed here in the present invention are hollow, but the ones provided with cores may be used to enhance their sensitivity.

Three magnetic field generators are employed in the preferred embodiment, intending to make smaller the error which varies depending upon in what direction the magnetic field generators are directed, but one magnetic field generator may be allowed. If the magnetic field generators are increased in number, say, six or twelve, more accuracy can be guaranteed in measurement.

As described above, the present invention enables the distance between two points in a cube or in three dimensional space to be obtained. Preferred embodiments further enable a certain value to be obtained independent of the direction in which the sensors and the generators are directed.

CLAIMS

1. A distance measuring sensor comprising at least one magnetic field generator means for generating magnetic field, first, second and third converter means arranged near one another to convert magnetic field to voltage, said magnetic field generated through the magnetic field generator means, and an operational means, wherein, in use, outputs of the converter means are applied to the operational means to get data relating to those distances which are between the magnetic field generator means and the converter means.

2. A distance measuring sensor comprising first, second and third magnetic field generator means arranged near one another to generate magnetic fields, first, second and third converter means arranged near one another to convert magnetic fields generated through the magnetic field generator means to voltages, and an operational means, wherein, in use, magnetic field generated by the first magnetic field generator means is converted to voltages through the first, second and third converter means, magnetic field generated by the second magnetic field generator means is converted to voltages via the first, second and third converter means, magnetic field generated by the third magnetic field generator means is converted to voltages through the first, second and third converter means, and the voltage values thus obtained through the first, second and third converter means are operationally processed by the operational means to get data relating to those distances which are between the first, second, third magnetic field generator means and the first, second, third converter means.

3. A distance measuring sensor according to claim 2 wherein each of the first, second and third magnetic field generator and converter means consists of a coil wound in mutually perpendicular planes around a sphere or cube.

4. A distance measuring sensor according to claim 2 or 3, wherein magnetic fields generated through the first, second and third magnetic field generator means are of alternating current, the operational means comprises detectors, squaring units, an adder and a function generator, voltages obtained through the first, second and third converter means are detected by the detectors, outputs of the detectors are added by the adder, and outputs of the adder is applied to the function generator.

5. A distance measuring sensor according to claim 4 wherein the function generator consists of a sixth power root converting circuit and a reciprocal number converting circuit so that the output of the adder may be converted to sixth power root by means of the sixth power root converting circuit and that output of the sixth power root converting circuit may be converted to reciprocal number by means of the reciprocal number converting circuit.

6. A distance measuring sensor according to claim 2 or 3, wherein the operational means consists of analog/digital converter means and a micro-processor.

7. A distance measuring sensor comprising an oscillator means for generating alternating current, first, second and third coils arranged near and mutually perpendicular to one another first, second and third switching means for applying output of said oscillator means to the coils, first, second and third converter means arranged near and mutually perpendicular to one another to convert magnetic fields generated through the coils to voltages, a detector means for detecting outputs of said converter means, first, second and third squaring means for squaring output of said detector means, a first adder means for adding outputs of said first, second and third squaring means, first, second and third memory means, a second adder means for adding outputs of said first, second and third memory means, an operational means for raising output of said second adder means to the one sixth power and converting the resultant to a reciprocal number or converting output of said second adder means to a reciprocal number and raising the reciprocal number to the one sixth power, and a control means, wherein, in use, said control means causes the first switching means to be turned on to store output of said first adder means in the first memory means, the second switching means to be turned on to store output of said first adder means in the second memory means, and the third switching means to be turned on to store output of the first adder means in the third memory means, so that distances between the first, second and third magnetic field generator means and the first, second and third converter means may be measured.

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